

A CONTRIBUTION TO THE BIOLOGY OF THE BLUE
SWIMMING CRAB, *NEPTUNUS PELAGICUS* (LINNAEUS),
WITH A NOTE ON THE ZOEAE OF *THALAMITA CRENATA*
LATREILLE¹

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(With a plate and fifty-eight figures)

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INTRODUCTION

Considerable work has been done on the biology and fisheries of crabs especially the edible crab of the Pacific coast of North America, *Cancer magister*.² Hay (1905), Churchill (1918, 1941 and 1942), Hopkins (1943 and 1944) and Sandoz and Hopkins (1944) have contributed to the life history of the Portunid crab, *Callinectes sapidus*. Lebour (1928) has given a detailed account of the larvae of Portunids of the Plymouth area.

The authors have, in a previous report (1951), made reference to the fishery and fishing methods for *Neptunus pelagicus* the most

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² For a list of references on *Cancer magister* refer Clever (1949).

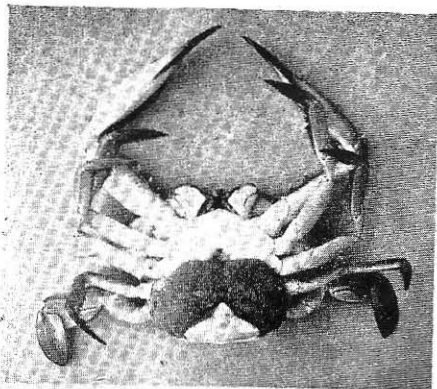


Photo 1

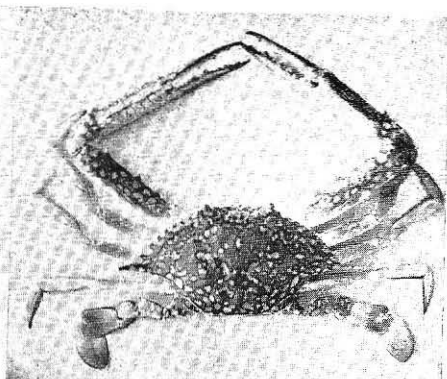


Photo 2



Photo 3

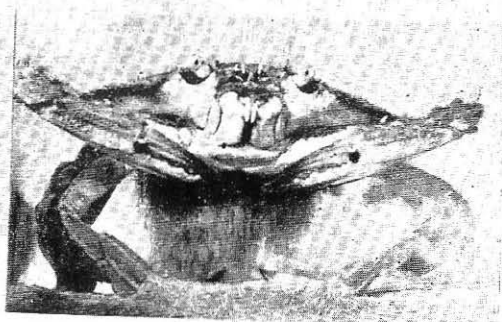


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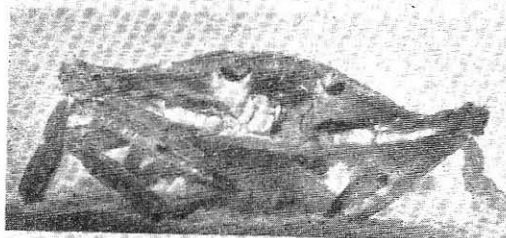


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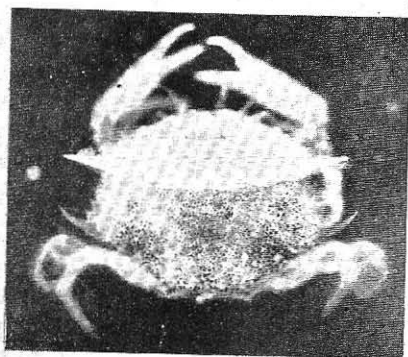


Photo 6

Photo 1. A female *Neptunus pelagicus* showing the 'berry' (130 mm. width of carapace).

Photo 2. A male of the same species. 150 mm. width of carapace.

Photo 3. A female *N. pelagicus*. Width of carapace, 140 mm.

Photos 4 and 5. Female crabs during the process of shedding the eggs.

Photo 6. A juvenile 8.5 mm. during the process of moulting.

common Portunid crab occurring near Mandapam. Little is known about the biology of this species and except for brief reports by Stead (1898) on the genus *Neptunus* and Delsman and De Man (1925) on the 'Radjungans' of the Bay of Batavia there is no detailed account on its development, growth and breeding. The latter have described three stages of zoeae and the megalopa. Their assumption that the various zoeae and the megalopa they were describing, belong to *N. pelagicus* was based only on circumstantial evidence because no other species of crab occurred in large numbers in the area of study. All the larvae, except the ones they dissected out from the eggs, were obtained from plankton. Thomson (1951) has dealt with the catch composition of *N. pelagicus* in the Moreton Bay, Australia.

Although crab fishery is not a major industry in India, it is a source of income to many fishermen of this area particularly during the off-season. At the present rate of exploitation the possibility of depleting the stock may not happen in the immediate future. But in course of time the crab fishery, like any other fishery of our country, has possibilities of expansion. When such expansion takes place, regulatory measures will have to be enforced to safeguard the fishery as is done in other countries where crab industry has assumed a major importance. The existing knowledge of the life history of *N. pelagicus* is fragmentary and not entirely reliable. Detailed investigations were heretofore undertaken on this species with a view to collecting as much data as possible to complete a fairly satisfactory picture of its life history.

The authors wish to record here their appreciation of the excellent co-operation they received from the fishermen and the crab vendors, without whose help it would not have been possible to complete this piece of work.

MATERIAL AND METHODS

The habits of the crabs are difficult of direct observation as they are found in fairly deep waters, and as such most of the details, recorded here were observed under aquarium conditions.

Berried crabs were collected from the commercial catches as soon as the nets were hauled out of the water. They were brought to the laboratory in earthenware containers with sea water and released in large glass aquaria with about three inches of sand at the bottom and nearly six inches of water. The crabs seldom survived for more than three or four days in tanks without sand or sufficient water to cover them completely. The berried crabs were never found to feed in the aquaria although plenty of food in the form of pieces of fish, prawns etc., was provided. For most of the time they remained fully buried in the sand with their eyes and antennae alone projecting.

Zoea larvae and megalopae obtained from plankton were kept in small bowls. Because of the cannibalistic tendencies of the megalopae it was found necessary to keep only one in a bowl at a time. Although several efforts were made to rear the zoeae through the different stages, only two attempts proved successful. The zoeae were fed with various planktonic larvae and the megalopae with small bits of muscles of prawns, fish and molluscs.

HABITS AND HABITAT

Neptunus pelagicus occur in large numbers near Mandapam at depths up to about three fathoms and prefer a sandy or sand and mud bottom. They are active and swim sideways with the aid of the last pair of flattened swimming legs as MacGinitie (1949) has described in the case of *Portunus xantusi*: 'As they swim sideways they streamline themselves by sticking one "elbow" of the large claw ahead and leaving the legs of the opposite side straight out from the body.' After leaving the planktonic life the post-larval crabs settle down at the bottom. Just like many other species of crabs these also are scavengers and cannibals. In the aquarium these crabs have been observed to be feeding voraciously on pieces of clam meat, dead prawns and small fish.

There are evidences to show that individuals tend to segregate according to size and sex. The larger ones are generally found in deeper water, whereas the smaller ones inhabit shallower areas. This segregation according to size is clearly seen from the landings of two types of nets operated at different depths. The size frequency distribution of crabs caught by the 'nandu valai'¹ is given in Figure 1 which shows that the majority of crabs landed are above 90 mm. and those below 80 mm. have not been caught. This net is usually laid at depths varying from one to one and a half fathoms, whereas the 'konda valai'² which is generally operated from a depth of about three feet catches crabs which invariably never exceed 80 mm. in carapace width. The size frequencies of crabs caught by the 'konda valai' are shown in Figure 2. Segregation according to sex is observed only among the larger individuals.

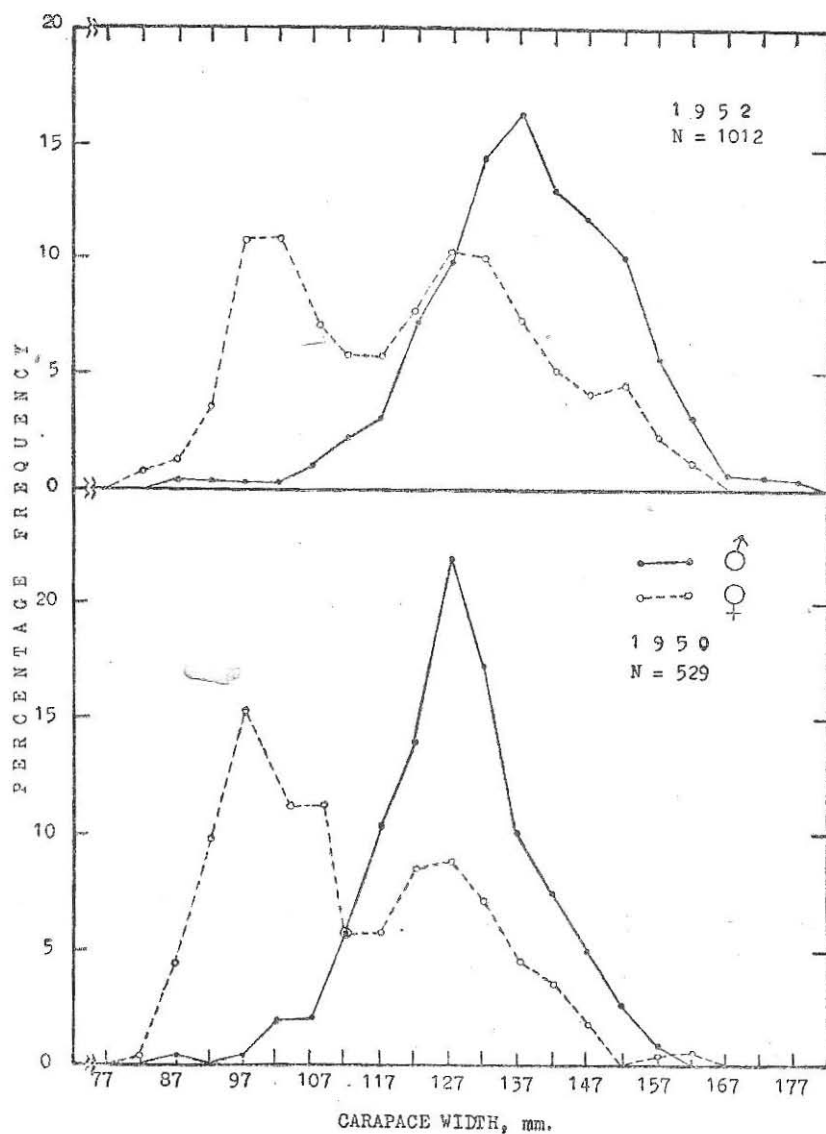
The crabs are able to withstand considerable variations in temperature and salinity. This is seen from the fact that they are found in fair numbers in the shallow lagoons near the Palk Bay during February when the temperature in the lagoon may go up as far as 35°C and the salinity as high as 43 ‰. However, during March a marked decline in their numbers was observed in the same area and several dead ones were also noticed, perhaps, due to the very high temperature (40°C) and salinity (67.86‰). Similarly they are also found in large numbers in localities where the salinity is very low. Kemp (1915) has observed that *N. pelagicus*: '... is common in the Chilka Lake, both in the outer channel and in the main area; ... It is, apparently, unaffected by alterations in salinity and is equally abundant at all seasons of the year.'

BREEDING HABITS AND SEASON

Stead (1898) has remarked that the spawning season of *Neptunus* in Australian waters is about August to November, whereas according to Thomson (1951) the egg bearing season is from September to April. Delsman and De Man (1925) have not observed any such

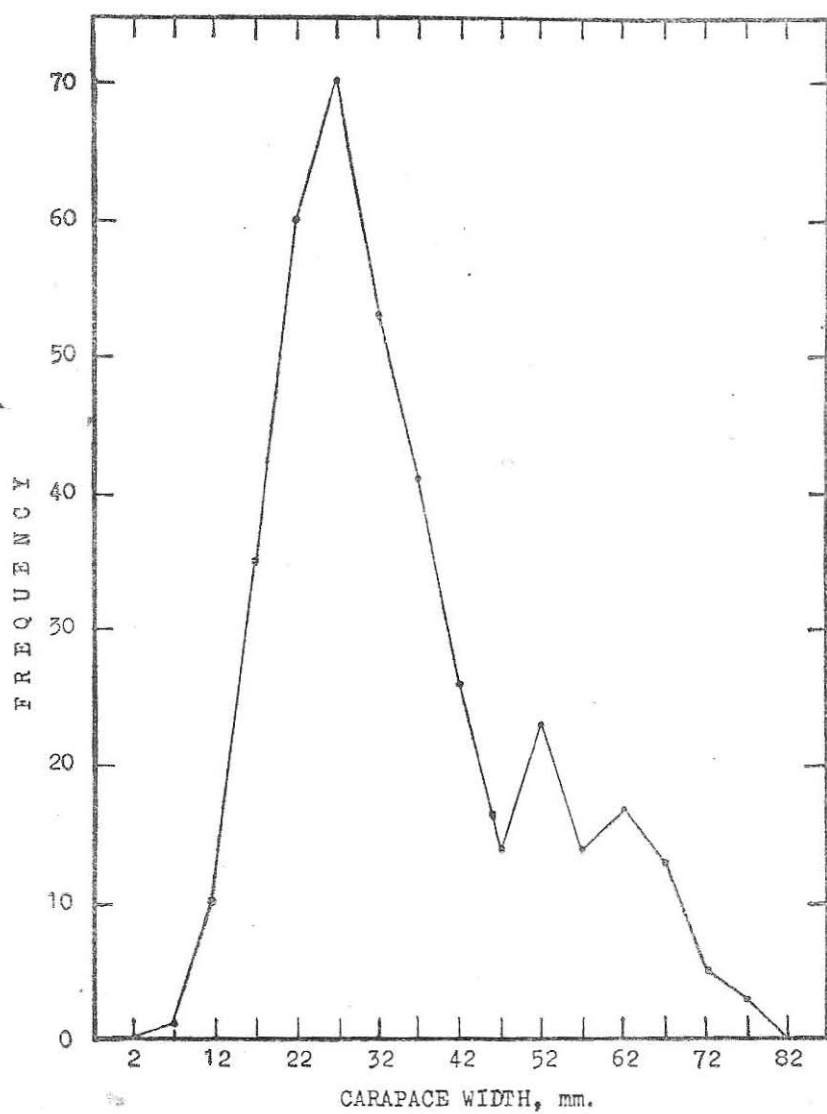
¹ For details regarding 'nandu valai' refer Prasad and Tampi (1951).

² A small drag net which is used in shallow waters to catch prawns and small fish. For details refer 'Preliminary guide to Indian fish, fisheries, methods of fishing and curing'. Government of India, Agricultural Marketing Series No. 24, 1941.



Neptunus pelagicus

Fig. 1. Size frequencies of male and female crabs landed at Vedalai.



Neptunus pelagicus

Fig. 2. Size frequency distribution of crabs caught in the 'konda valai'.
Sexes combined.

definite breeding period for *N. pelagicus* in Batavia and remark that berried crabs occur throughout the year. Although berried individuals are found throughout the year, observations made locally on the commercial landings as well as occurrence of larval forms in the plankton tend to point to the fact that the maximum breeding activity is during September to March.

Juveniles ranging from 15 to 35 mm. in carapace width were common during November to December and those from 35 to 60 mm. were obtained during February from the Palk Bay lagoons. Results of rearing experiments conducted in the laboratory showed that it took approximately one month for a megalopa to reach 8.5 mm. in carapace width after four successive moults and under the same conditions a juvenile 15 mm. attained a size of 23 mm., after two moults, during the course of three weeks. From these it may be safe to assume that the juveniles obtained from the lagoons during November-December and February belong to the first year class which perhaps were spawned during September-October.

Delsman and De Man (1925) have given an account of the copulation in this species. The eggs are attached to the long endopoditic setae of the abdominal appendages of the female. The mode of attachment of the eggs is not clearly understood although it was believed by the earlier workers that a sticky substance is secreted around the eggs as they are shed. Another theory has been the one put forward by Williamson (as given by Pearson, 1908) who suggested that the endopoditic seta penetrates the chorion of the eggs in two places and thus the egg becomes skewered on the seta. The piercing of the chorion liberates an adhesive perivitelline fluid, which is believed to assist in making the attachment more permanent. The chorion eventually becomes drawn out at the point of attachment as a result of which the egg appears to be attached to the seta by a stalk. But in the opinion of the present authors the mode of attachment of the eggs in *N. pelagicus* seems to be similar to the one described by Yonge (1937) in the lobster, *Homarus vulgaris*. He states: 'The eggs are fastened to the nonplumose setae, either directly or by way of other eggs so attached, in all cases by means of twisted strands of a transparent cement . . . which constitute the "funiculus" of many authors. This substance also extends around each egg, forming the outer membrane which adheres closely to the surface of the egg. . . . The outer membrane is, according to him, cuticular in nature, whereas the inner one is chitinous. He observed similar membranes in the eggs of *Cancer pagurus* and *Carcinus maenas*. The eggs of the species under discussion also show the two membranes, the inner and the outer corresponding to the two membranes described by Yonge.

The female crab carries the eggs (Photo 1) until they complete their development and the larvae hatch. Crabs in 'berry' often remain buried in the sand and come out only occasionally perhaps for the aeration of the eggs.

SIZE AT MATURITY AND SEXUAL DIMORPHISM

The smallest crab, so far observed, bearing eggs was 106 mm. and the largest 163 mm. in carapace width. According to Thomson

(1951) the smallest crab bearing eggs was 4.2 inches and the largest 7.1 inches. There is very good agreement in size between the smallest berried crab recorded by Thomson in Australian waters and that recorded by the authors although the largest observed by him is much bigger than the one recorded locally. Figure 3 shows the percentage of ovigerous crabs at different size groups caught at Vedalai. The maximum number was seen in the size range between 125 and 140 mm. in carapace width.

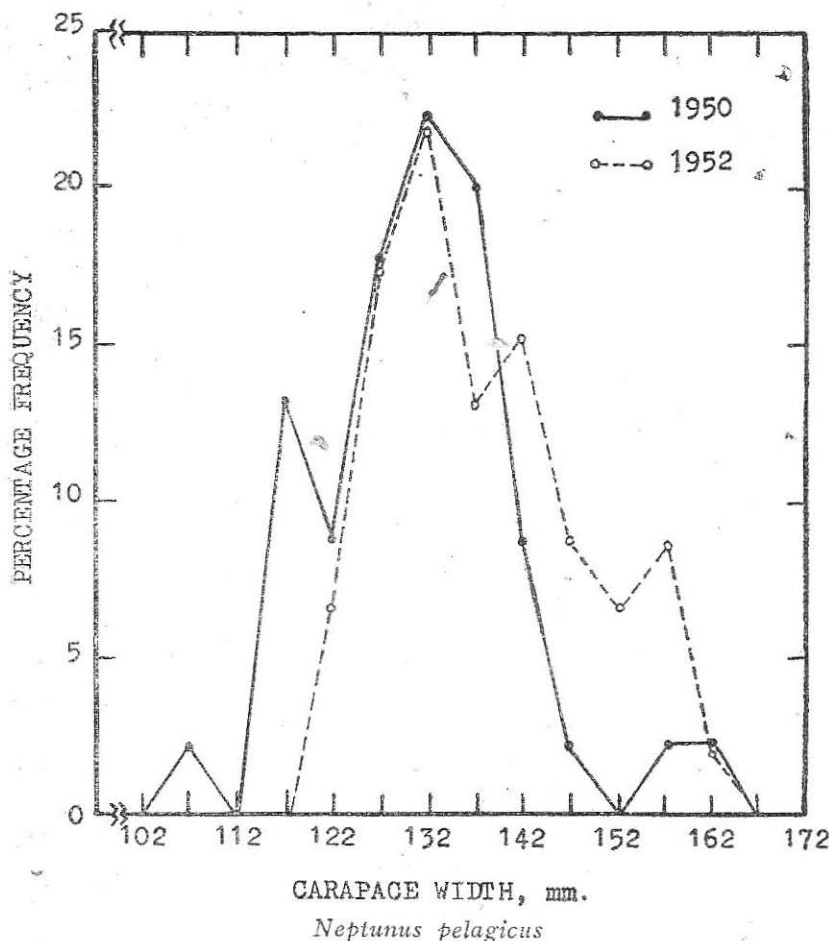


Fig. 3. Percentage of berried crabs in the different size groups.

In addition to the direct observations made on the commercial catches, evidences leading to the conclusion that females attain maturity at a carapace width of approximately 108 mm. are forthcoming from studies made on the relative growth¹. The width of

¹ Full details of the study on the relative growth of parts in *Neptunus pelagicus* will be published in course of time.

the sixth abdominal segment and the relative growth of the first walking leg in females show abrupt changes at a carapace width of about 108 mm. which may be attributed to the onset of maturity. In the case of males no attempts were made to determine the size at maturity based on the examination of the testes but evidences obtained from the study of relative growth suggest that they attain maturity at a slightly earlier stage. Changes in the relative growth of the first walking leg and the chela were observed in the males at a width of about 102 mm. It is possible that these changes are indicative of the attainment of sexual maturity.

Males and females exhibit distinct sexual dimorphism. The males are brilliantly coloured with the walking and swimming legs having bright blue colour (hence the popular name 'Blue crab') while the females are dull and as Deisman and De Man (1925) have remarked the females do not deserve the name 'Blue crab'. There are no marked differences in the general shape of the carapace between the males and females but the males have relatively longer chelipeds and first walking legs (Photos 2 and 3). The males grow to a bigger size than the females and the largest male recorded in this area is 178 mm. whereas the maximum size of females recorded for this area is only 163 mm.

SEX RATIO

There has always been a preponderance of males over females and the average ratio is 2.4 males to each female. Thomson (1951) has observed that in the Cleveland area the proportion of males to females may be as high as 4.3:1. The greater preponderance of male crabs he attributes to swarming or schooling according to sex. Amongst the juveniles (size ranging from 35 to 80 mm.) there is apparently no marked difference in the sex ratio. From the few samples of juveniles examined it may be said that the ratio of males to females is 1.07:1. This may be due to the fact that there is no segregation by sex within this group.

PARASITIZATION

The data collected from landings near Mandapam show that the incidence of parasitization by the rhizocephalan parasite is low. A little over 2 per cent of the crabs was seen infected but this percentage includes only those crabs in which the parasite was visible externally. George (1943) has remarked that out of the 519 specimens of *Neptunus pelagicus* collected by him at Madras nearly 20 per cent were found to be infected.

DEVELOPMENTAL STAGES AND LARVAL HISTORY

Eggs. The freshly spawned eggs are bright yellow in colour. The number of eggs in a 'berry' is found to vary considerably. A female 157 mm. across the carapace was found to have approximately 191,500 eggs while another one 122 mm. in carapace width carried ca. 455,000 eggs. There does not seem to be any definite number

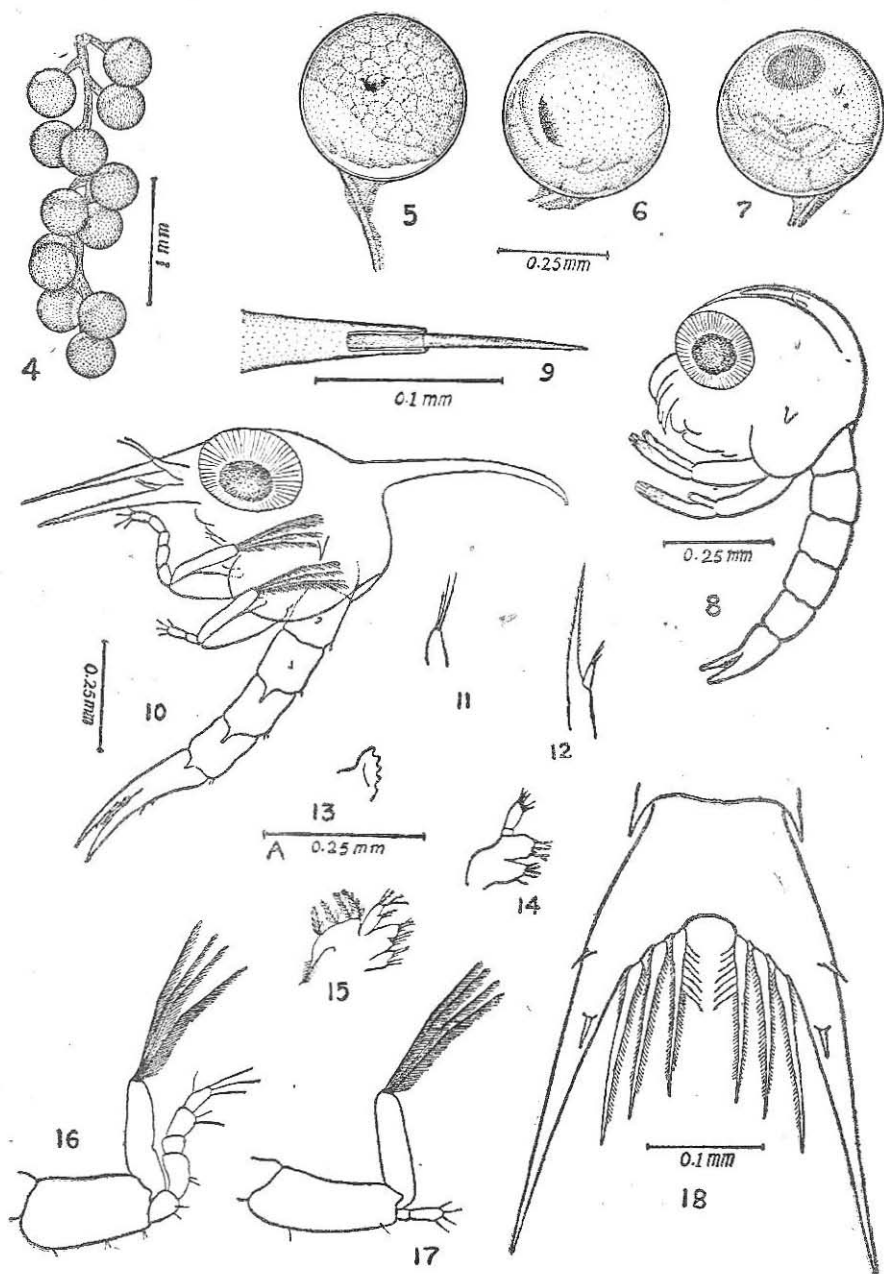
of eggs attached to each seta of the pleopod. Figure 4 shows a few eggs attached to the seta. The eggs are spherical with a diameter of 360 to 375 micra, and are surrounded by two membranes, an inner and an outer membrane. Both these membranes are transparent and the yolk is visible as yellow granules with the surface divided into large polygonal areas. No attempts were made at a detailed study of the early embryonal development.

Externally certain changes in the eggs are visible as development progresses. First the animal pole becomes transparent, then the eye spots begin to appear as brownish patches. Gradually the rudiments of the abdomen and cephalic and thoracic appendages are formed (Figs. 5, 6 and 7). Along with these changes the eggs gradually change their colour. From bright yellow they become light brown and then greenish black in the advanced stages. As the embryo grows xanthophores appear on either side of the cephalothorax and abdomen. Just before the larvae are to be liberated the developing zoea can be seen through the transparent egg membrane. At this stage the eyes are black and well developed. The abdomen is curved inwards in such a way that the telson covers the rostral end of the head. It takes about ten days for this development to be completed. All the berried crabs kept in the aquarium liberated the eggs in seven or eight days.

When the embryonic development is complete and just when the larvae are about to hatch the eggs are liberated from the pleopods by a conscious effort on the part of the female crab which carries the eggs. The crab, which mostly remains buried in the sand, comes out and raises its whole body on all the walking legs (Photo 4). The abdomen is fully stretched and the pleopods bearing the eggs are vigorously jerked. As a result of this the groups of eggs round each seta get themselves loosened from the bunch and thereby the compactness of the 'berry' is lost. A few of the eggs are shed during this process but most of them are combed out from the endopoditic setae usually with the help of the stiff hairs along the margin of the terminal segment of the second and third pairs of walking legs (Photo 5). In *Cancer pagurus* Pearson (1908) has observed that the last walking legs are used for the purpose of detaching the larvae from the pleopods. All the eggs are shed in about two hours' time as was observed in a specimen kept in the aquarium. It is a common belief among the local fishermen that the females spawn only once in their life-time and after liberating the eggs they do not live long. The specimens on which the above observations were made died soon after liberating the eggs on the eighth or ninth day of their capture.

Some of the eggs hatch while they are being detached from the endopodites of the abdomen but the majority of them sink to the bottom where the egg membranes burst and the larvae emerge. It has been observed in all cases that the egg-capsules break into two equal halves along a plane perpendicular to the plane of attachment.

In the following pages an attempt is made to give an accurate and detailed description of all features which may be of importance in separating the larvae from those of the different species of *Portunids* occurring in this area.



Neptunus pelagicus

- Fig. 4. A group of eggs attached to the seta of the pleopod.
 „ 5, 6 and 7. Three stages in the development of the egg.
 „ 8. Pre-zoea.
 „ 9. A spine showing the telescopic nature.
 „ 10. First zoea.
 „ 11. First antenna
 „ 12. Second antenna
 „ 13. Mandible
 „ 14. First maxilla
 „ 15. Second maxilla
 „ 16. First maxilliped
 „ 17. Second maxilliped
 „ 18. Telson

Scale line A stands for figures
 11 to 17.

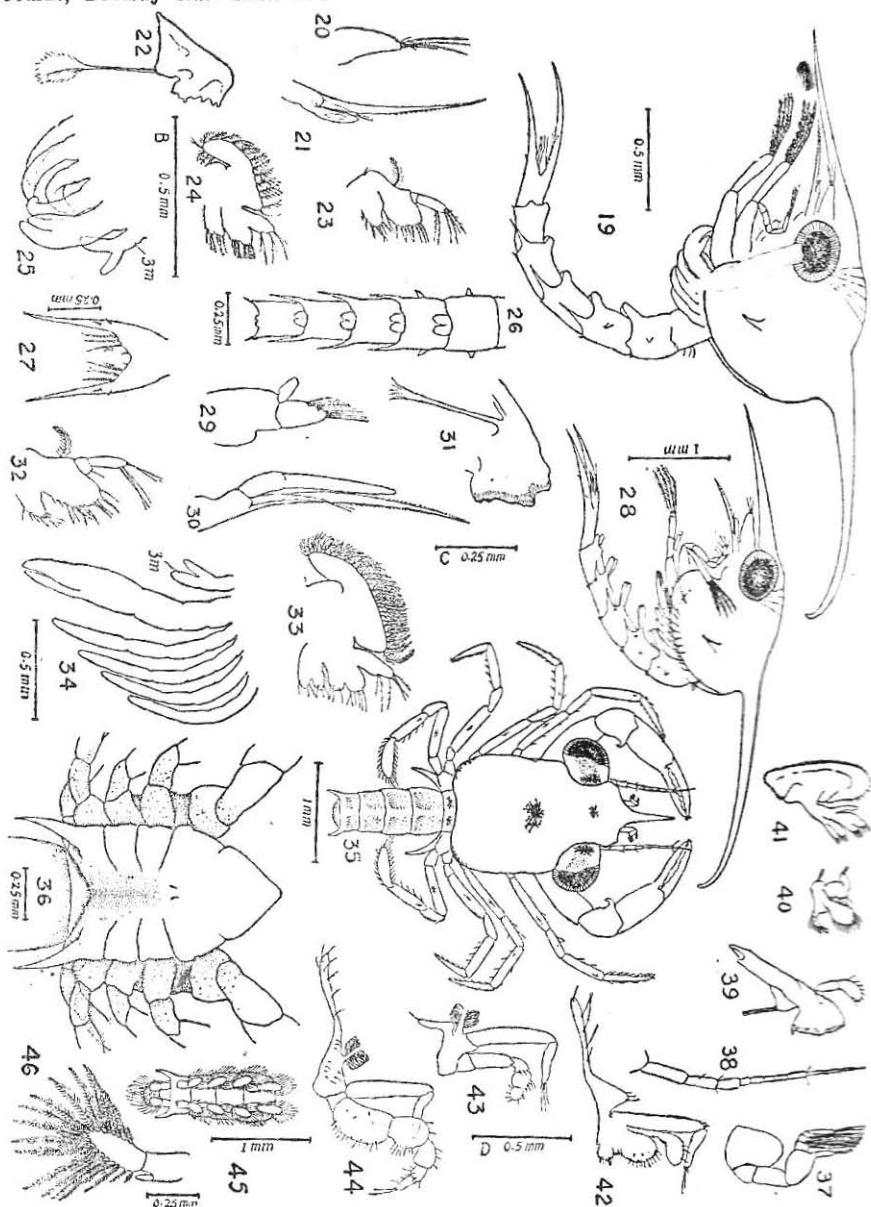


Fig. 19. Second zoea
 „ 20. First antenna
 „ 21. Second antenna
 „ 22. Mandible
 „ 23. First maxilla
 „ 24. Second maxilla

„ 25. Thoracic appendages
 „ 26. Abdomen
 „ 27. Telson
 „ 28. Third zoea
 „ 29. First antenna
 „ 30. Second antenna
 „ 31. Mandible
 „ 32. First maxilla
 „ 33. Second maxilla
 „ 34. Thoracic appendages
 „ 35. Megalopa
 „ 36. Sternal plate of the last thoracic segment showing the spine
 „ 37. First antenna
 „ 38. Second antenna
 „ 39. Mandible
 „ 40. First maxilla

Neptunus pelagicus

Fig. 25. Thoracic appendages
 „ 26. Abdomen
 „ 27. Telson
 „ 28. Third zoea
 „ 29. First antenna
 „ 30. Second antenna
 „ 31. Mandible
 „ 32. First maxilla
 „ 33. Second maxilla
 „ 34. Thoracic appendages
 „ 35. Megalopa
 „ 36. Sternal plate of the last thoracic segment showing the spine
 „ 37. First antenna
 „ 38. Second antenna
 „ 39. Mandible
 „ 40. First maxilla
 „ 41. Second maxilla
 „ 42. First maxilliped
 „ 43. Second maxilliped
 „ 44. Third maxilliped

Scale line B is for figures 20 to 25

Scale line C stands for figures 29 to 33.

Scale line D stands for figures 37 to 44.

Fig. 31. Mandible
 „ 32. First maxilla
 „ 33. Second maxilla
 „ 34. Thoracic appendages
 „ 35. Megalopa
 „ 36. Sternal plate of the last thoracic segment showing the spine
 „ 37. First antenna
 „ 38. Second antenna
 „ 39. Mandible
 „ 40. First maxilla
 „ 41. Second maxilla
 „ 42. First maxilliped
 „ 43. Second maxilliped
 „ 44. Third maxilliped

Pre-zoea (Fig. 8). The newly hatched larva may be distinguished as the pre-zoea. It is enclosed in an extremely thin embryonic cuticle and has a soft body. This larva remains for some time at the bottom without much active movement except for occasional jerks presumably to cast off the embryonic cuticle. At this stage the front spine of the carapace is bent inwards and almost hidden between the pair of large eyes while the posterior spine remains flexed forwards over the carapace. Both these spines as well as the two forks of the telson have a telescopic construction (Fig. 9). The appendages, although they are free from the body still remain enclosed in sheaths with the terminal setae retracted. The spiniform process of the antenna is short. After the embryonic cuticle is shed the spines of the carapace and the telson get themselves extended presumably due to pressure exerted by the larva and they attain their full length. The larva assumes all the characters of the first free swimming zoea in the course of about two hours. Then the larva moves about actively at the surface. This stage is referred to as the first zoea.

First zoea (Fig. 10). The larvae hatched in the laboratory did not survive for more than twenty hours. Corresponding stages were observed in the plankton taken within one and a half miles from the shore of the Gulf of Manaar and the Palk Bay during September to March. In general appearance this zoea resembles that of many of the Portunids and measures about 1.3 mm. between the tips of the two spines and including the telson the larva is 1.25 mm. in length. The posterior spine of the carapace varies slightly in length and is about 0.5 mm. long terminating in a curved tip while the rostral spine is 0.3 mm. in length and is almost straight and pointed. There is one pair of short lateral spines on the carapace.

First antenna (Fig. 11). It is short and bears three aesthetes at its tip.

Second antenna (Fig. 12) consists of a well developed spiniform process which is nearly as long as the rostral spine and a small exopodite bearing two short setae.

Mandible (Fig. 13) is a single hard chitinous piece with four or five blunt teeth at its cutting edge.

First maxilla (Fig. 14). There is no epipodital hair. The protopodite has two lobes, the proximal or coxopodite bears four setae and the basipodite has five setose spines. The endopodite is two segmented and there are five setae on the terminal segment which is longer than the proximal joint.

Second maxilla (Fig. 15) has six setae on the coxopodite arranged in two and three, eight on the basipodite and six on the endopodite. The scaphognathite is flat and narrow with five plumose setae on its margin.

First maxilliped (Fig. 16). The basipodite bears five setae. There are four long terminal setae or 'swimming hairs' on the exopodite. The endopodite is five jointed and the segments are of unequal length. Two setae are present on the proximal segment as well as the second segment which is the longest. The third segment has no seta while the fourth bears two setae and of the five on the last segment three are long and terminal.

Second maxilliped (Fig. 17) has two setae on the basipodite. The exopodite bears four long 'swimming hairs'. The endopodite which is short and two jointed bears four terminal setae on the basal segment.

Third maxilliped is not formed.

Abdomen shows only five segments, the last one being fused with the telson. All the abdominal segments have a pair of small hairs on the dorsal side. There is a pair of short lateral spines or hooks on the second and third segments. The third, fourth and fifth segments possess a pair of long and downwardly pointed spines from the postero-lateral border. Chromatophores are present on the third to fifth abdominal segments. The pleopods have not been developed yet.

Telson (Fig. 18) is deeply forked with three pairs of long spines between the forks and two pairs of short spines on the dorsal side of each of the fork as shown in the figure.

Second zoea (Fig. 19). Striking differences from the previous stage are the increase in the size of the larva and the appearance of the rudiments of the thoracic and abdominal appendages. The zoea measures about 3 mm. from spine to spine and is 3.25 mm. in length. The rostral spine is nearly 1 mm. and the posterior one is longer (1.2 mm.) with a downwardly curved tip.

First antenna (Fig. 20) has six aesthetes.

Second antenna (Fig. 21). The spiniform process is much shorter than the rostral spine. The flagellum or the endopodite has made its appearance and is unjointed.

Mandible (Fig. 22). The cutting edge shows a number of irregular teeth and the mandible is provided with well developed muscular tendons attached to its base.

First maxilla (Fig. 23) has two epipodital hairs of which one is plumose. The coxopodite bears eight or nine setae and the basipodite has eight setae. The endopodite is two jointed like that of the previous stage and has six terminal setae.

Second maxilla (Fig. 24) resembles in general shape that of the first zoea with two groups of three setae each on the coxopodite, two groups of five and six setae on the basipodite and six on the endopodite. The scaphognathite is broader with seventeen plumose setae on its margin.

First and second maxillipeds retain their shape and swimming function.

Third maxilliped also has appeared as a rudiment with two lobes (Fig. 25: 3m).

Thoracic appendages. Rudiments of these show the large cheliped and the four walking legs (Fig. 25). However, the segmentation of these appendages is not very clear.

Abdomen. All the six abdominal segments are distinct. The first segment has three dorsal hairs and does not show the pleopods. Segments two to five possess a pair of prominent protuberances on the ventral side which are the rudiments of the pleopods. The sixth segment also shows the developing pleopods but they are much smaller than the rest. Short lateral spines are present on the second

and third segments and the spines on the postero-lateral border of segments three, four and five have become longer (Fig. 26).

Telson has the same shape as that of the first zoea but it shows an additional pair of small spines in the middle of the fork (Fig. 27).

The transition from the first to the second zoea has not been observed in the laboratory. But from a series of collections and comparison with the stages described by Delsman and De Man (1925) it may safely be assumed that there is no intermediate stage between the first zoea described above and the second zoea here described.

It has been possible to get the second zoea metamorphosed in the laboratory into the third zoea stage. A single zoea of the second stage obtained from plankton on January 16, 1952 moulted into the next stage on January 18.

Third zoea (Fig. 28). It measures 5 mm. from end to end of the spines and is 4 mm. in length and is thus much longer than the previous stage. The rostral spine is 1.5 mm. and the posterior spine is 2 mm. long. There are a few very small spines at the postero-lateral margin of the carapace. The thoracic and abdominal appendages are better developed. Only slight changes are observed in the cephalic appendages.

First antenna (Fig. 29) is two jointed. The terminal segment has three groups of long aesthetes. The basal segment is enlarged and has a short flagellum.

Second antenna (Fig. 30) retains the long spiniform process which is only half as long as the rostral spine. The flagellum or the endopodite shows two indistinct segments while the exopodite is short and unsegmented with two terminal setae.

Mandible (Fig. 31) has grown stouter and has irregular teeth.

First maxilla (Fig. 32) has only one plumose seta on the epipodite. The coxopodite is smaller than the basipodite, the former with eight setae and the latter has twelve setae of which only six are spinous. On the small basal segment of the two jointed endopodite there is a single seta and the terminal segment carries five long setae.

Second maxilla (Fig. 33) has seven setae on the coxopodite, ten on the basipodite and six on the endopodite. The scaphognathite is broad and carries twenty-eight plumose setae.

First and second maxillipeds are the same as in the previous stage.

Third maxilliped. Just in front of the cheliped the third maxilliped can be seen still remaining as a rudiment (Fig. 34: 3m).

Thoracic appendages are distinctly segmented (Fig. 34).

Abdomen. The lateral spines on the second and third abdominal segments and also the long postero-lateral spines on segments three to five are present. On the dorsal side of the first segment there are three hairs and the other segments have a pair of short dorsal hairs. The pleopods, although rudimentary, show the two jointed nature with a short basal segment and a longer distal one. They are present in segments two to six, the last one being smaller than the others.

The third zoea directly metamorphosed into the megalopa. A zoea obtained on January 11, 1952 metamorphosed in the laboratory into a megalopa on the next day.

Megalopa (Fig. 35) retains the rostral spine. The size of the megalopa may vary and from the tip of the spine to the posterior border of the carapace it measures usually 2 mm. in length and 1 mm. in width across the broadest part. Megalopae ranging in size from 1.9×0.9 mm. to 2.25×1.25 mm. have been collected from plankton. It often swims about near the surface with the aid of the setose pleopods. The chelipeds and the pereopods are also fully formed and the latter are used for walking when the megalopa sinks to the bottom.

The carapace has one or sometimes two large median chromatophores, one branching chromatophore on each optic peduncle and a pair of smaller ones on the dorsal side of the first abdominal segment. The third and fifth segments of the pereopods also have small chromatophores. Like many of the Portunid megalopae this too has two long backwardly pointed spines from the sternal plate of the last thoracic segment (Fig. 36). Delsman and De Man (1925) have said that the spines originate from the basal joint of the last pair of pereopods. Looking at these spines from the dorsal side one may get the impression that these originate from the last segment of the walking legs but an examination from the ventral side reveals clearly that these are only prolongations of the sternal plate of the last thoracic segment.

First antenna (Fig. 37) has eight segments on the main branch of which the basal one is the largest. The last four segments are relatively smaller and they bear bunches of aesthetes. There is a short flagellum with two terminal aesthetes on the fourth segment.

Second antenna (Fig. 38) consists of a broad basal segment and a long eleven jointed endopodite. The spiniform process of the exopodite of the zoea has completely disappeared.

Mandible (Fig. 39) has a short three jointed palp with its terminal segment bordered by hairy setae.

First maxilla (Fig. 40) is a small piece with three lobes.

Second maxilla (Fig. 41) has the scaphognathite broadened considerably than that of the zoea. Its marginal plumose setae have been replaced by numerous short hairs. The coxo- and basi-podites have been reduced in size with a few terminal setae. The endopodite is narrow and devoid of any setae.

First maxilliped (Fig. 42). The protopodite is produced inwards into a bilobed masticatory process armed with stiff setae. The endopodite is a single flat piece with four marginal setae near the tip. The exopodite is two jointed, the proximal one is long and has three setae while the distal segment is bent at right angles to the first segment and bears three long terminal setae. A long epipodite bearing a few thread-like setae arises from the coxopodite.

Second maxilliped (Fig. 43). Protopoditic segments are small. The coxopodite bears a short epipodite with a single seta, and a gill is also present. Endopodite has five segments the distal three of which are short and bent at right angles to the first two segments. All of them bear a number of setae. The exopodite is two jointed as that of the first maxilliped with four terminal setae on the distal segment.

Third maxilliped (Fig. 44). Protopoditic segments are reduced as in the second maxilliped. The endopodite is five jointed, the first

and second segments are flattened and bear a number of setae along the inner margin. The last three segments are bent like the corresponding segments of the second maxilliped and have many setae. Exopodite is two jointed, the second with a few terminal setae. An epipodite and a gill are also present.

Cheliped. In general structure it resembles that of the adult except that the segment next to the chela (carpopodite) has a small recurved spine at its inner border.

Pereiopods. The terminal segments of the last pair of legs are slightly flattened and have a number of long hairs. The other pereiopods almost resemble those of the crab.

Abdomen (Fig. 45). There are six segments and the telson. The first segment is relatively shorter than the rest and has no pleopods. The postero-lateral spines on the pleon-segments three and four have disappeared while those on the fifth segment persist. Segments two to six bear a pair of pleopods. Each pleopod (Fig. 46) consists of a protopodite, a flat exopoditic segment fringed with usually twenty long plumose setae and a short endopodite.

Telson is almost semicircular and entire without spines or setae.

The megalopa moults directly into the first post-larval instar with a flexed abdomen and a broad carapace with two lateral spines.

TABLE I

Details of megalopae reared in the laboratory

Date of capture and size of megalopa (mm.)	Date of moult and size (mm.)				
	I instar	II instar	III instar	IV instar	V instar
28-6-1951 1.10 × 2.00	29-6-1951 2.50 × 2.25	8-7-1951 4.75 × 3.25	12-7-1951 6.00 × 4.50	19-7-1951 7.00 × 5.00	28-7-1951 8.50 × 6.00
18-7-1951 1.15 × 2.00	19-7-1951 3.00 × 2.25	29-7-1951 5.00 × 3.50	—	—	—
18-1-1952 1.10 × 2.00	19-1-1952 2.50 × 2.10	27-1-1952 3.60 × 2.50	—	—	—
18-1-1952 1.10 × 2.00	19-1-1952 2.75 × 2.10	25-1-1952 4.00 × 2.75	—	—	—
18-1-1952 1.10 × 1.90	20-1-1952 2.50 × 2.10	27-1-1952 3.50 × 2.30	—	—	—

Note.—Of the measurements given, the first one refers to the width of carapace and the second the length inclusive of the rostral spine.

Several megalopae were obtained from plankton collections both from the Gulf of Manaar and the Palk Bay. Some of them moulted during the course of a few hours while most of them took about twenty-four hours to metamorphose. A few remained as megalopae for three days before metamorphosing into the first post-larval instar. A megalopa which was reared from a zoea obtained on January 11, 1952,

and second segments are flattened and bear a number of setae along the inner margin. The last three segments are bent like the corresponding segments of the second maxilliped and have many setae. Exopodite is two jointed, the second with a few terminal setae. An epipodite and a gill are also present.

Cheliped. In general structure it resembles that of the adult except that the segment next to the chela (carpodite) has a small recurved spine at its inner border.

Pereiopods. The terminal segments of the last pair of legs are slightly flattened and have a number of long hairs. The other pereiopods almost resemble those of the crab.

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18-1-1952 1.10 × 2.00	19-1-1952 2.50 × 2.10	27-1-1952 3.60 × 2.50	—	—	—
18-1-1952 1.10 × 2.00	19-1-1952 2.75 × 2.10	25-1-1952 4.00 × 2.75	—	—	—
18-1-1952 1.10 × 1.90	20-1-1952 2.50 × 2.10	27-1-1952 3.50 × 2.30	—	—	—

Note.—Of the measurements given, the first one refers to the width of carapace and the second the length inclusive of the rostral spine.

Several megalopae were obtained from plankton collections both from the Gulf of Manaar and the Palk Bay. Some of them moulted during the course of a few hours while most of them took about twenty-four hours to metamorphose. A few remained as megalopae for three days before metamorphosing into the first post-larval instar. A megalopa which was reared from a zoea obtained on January 11, 1952,

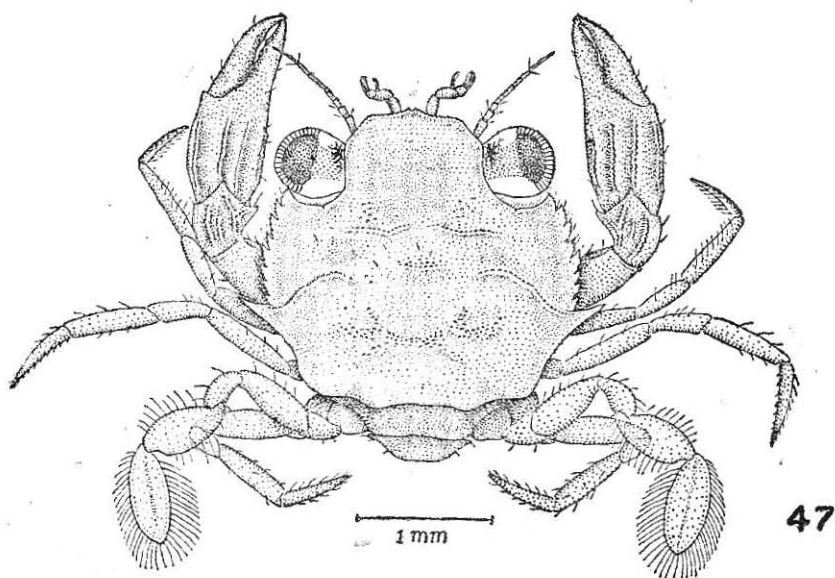
metamorphosed in the laboratory on the sixth day after becoming the megalopa. The moulting is a quick process and is usually completed in about fifteen minutes as observed in the laboratory. The splitting occurs along the posterior border of the carapace and the entire body is withdrawn from the shell which is cast off and the post-larval instar moves away from it.

Although several attempts were made in rearing these in the laboratory only a few were successful. Table 1 shows the details of megalopae which were successfully reared in the laboratory at least through two successive moults.

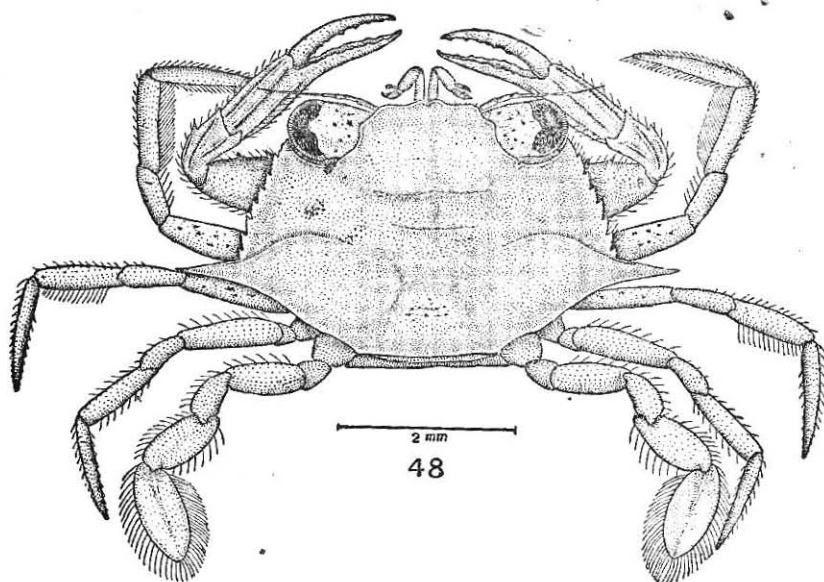
First Post-larval Instar (Fig. 47). The surface of the carapace is covered with pigment spots so as to give a dull grey colour which often matches well with the colour of the substratum and perhaps protects the young crab from its enemies. The rostral spine of the megalopa disappears during this metamorphosis. The carapace becomes wider and develops the marginal spines. Those reared in the laboratory measured 2.5 to 3.0 mm. in width and 2.1 to 2.25 mm. in length. It will be seen from the figure that the shape of the carapace at this stage is very much different from the fully grown crab. The proportion of length/width is approximately 1.11 in the first instar. The margin of the carapace between the eyes is nearly entire without teeth. The eyes are now lodged within shallow sockets. The large branching chromatophore on the eye-stalk still persists.

The appendages resemble very much those of the adult. The segments of the first antenna have become shorter, the flagellum of the fourth joint is reduced retaining the bunches of terminal aesthetes. The chela shows slight longitudinal ridges and a few hairs on it. Hairs have also developed particularly on the penultimate and last segment. The last pair of legs have become the swimming legs with flat paddle-like terminal segments as in the adult. The two backwardly directed spines of the last pair of sternal plates have disappeared completely. The abdomen is short with seven segments and fully flexed under the cephalothorax. The first and last segments do not possess any appendages. The flat pleopods of the megalopa which were used for swimming are replaced by slender appendages. The young crab remains at the bottom and seldom comes up to the surface.

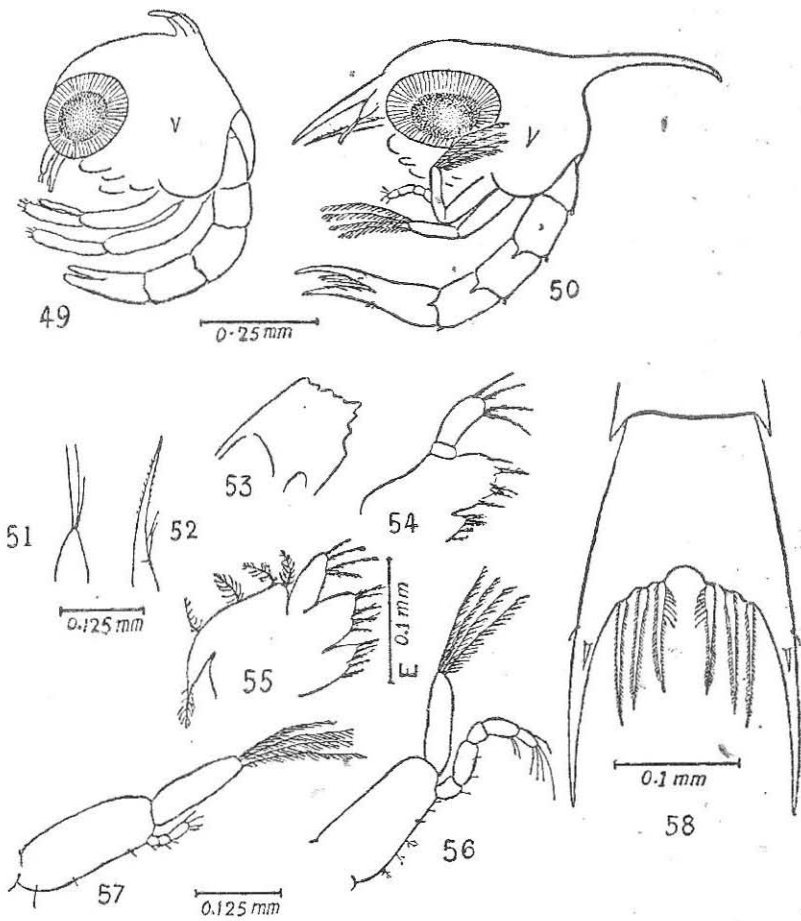
Second Post-larval Instar (Fig. 48). Under laboratory conditions it has been observed that the time taken for the first instar to moult into the second instar may vary from six to ten days. Considerable variation in the size at this stage has been observed in those reared in the laboratory (Table 1). The length/width proportion ranges from 0.65 to 0.70 and this proportion approximates more that of the adult than the first instar. The teeth on the anterior margin of the carapace between the eyes present in the adult are indicated by blunt projections. The large chromatophores on the eye stalk has broken up into small stellate ones. Small pigment spots are present uniformly all over the carapace and chelipeds. The young ones have now practically assumed most of the characters of the adult except for the colour and the shape of the carapace which they attain only after a series of successive moults. Photo 6 shows a juvenile 8.5 mm. in carapace width during the process of moulting.



Neptunus pelagicus
Fig. 47. First post-larval instar



Neptunus pelagicus
Fig. 48. Second post-larval instar



Thalamita crenata

- Fig. 49. Pre-zoea
 „ 50. First zoea
 „ 51. First antenna
 „ 52. Second antenna
 „ 53. Mandible
 „ 54. First maxilla
 „ 55. Second maxilla
 „ 56. First maxilliped
 „ 57. Second maxilliped
 „ 58. Telson

Scale line E is for figures
 53 to 55.

GENERAL REMARKS

Along with the study of the biology of *N. pelagicus* the authors maintained records of the size frequency of crabs landed at Vedalai for 1950 and 1952 in order to ascertain the relative proportion of different sizes caught. During 1950 the majority of the males landed varied from 120 to 143 mm., whereas in 1952 the males landed were slightly larger, 125 to 149 mm. As for the females in 1950 as well as 1952 the landings included apparently two age groups. In both the years the modes fall at almost the same size groups (Fig. 1). Studies on the biology have indicated that the males attain maturity when they are about 102 mm. and the females 106 to 108 mm. Although the females mature at 106-108 mm. majority of the ovigerous females caught are between 115 to 159 mm. (Fig. 3). This may mean that many of the females marketed now (Fig. 1) would not have had a chance to mate before they are captured. The position regarding the males is different. Majority of the males now landed are sufficiently grown up to be marketed.

It may be pointed out that if the industry expands the first step towards legislation will have to be the protection of berried crabs and then extend that to all females. Subsequently other legislative measures such as size limit on males and closed season *et cetera* may be enforced if found necessary. In this connection it may be mentioned that a certain amount of damage to the juveniles is caused by the use of 'konda valai'. As already mentioned elsewhere in this report very small crabs, sometimes in large numbers, are caught in the 'konda valai'. They are too small to be used for food and so the fishermen leave them on the beach where they die. This is a practice which should be discouraged. It is also necessary to take into consideration the use of bottom nets such as 'nandu valai'. This method, though efficient in catching crabs does not seem to be good because of the excessive handling of the crabs and consequent injury to those small ones and the females which are to be put back into the sea. Further detailed investigations on the population strength, intensity of fishing, rate of growth, rate of recruitment and other allied problems will have to be carried out at different centres before finally framing legislative measures.

NOTE ON THE ZOEAE OF *Thalamita crenata*

While examining the plankton for the zoea of *N. pelagicus*, the authors encountered several zoeae closely resembling those of *N. pelagicus*. Attempts were made to ascertain the identity of these zoeae. On January 18, 1952 a specimen of *Thalamita crenata* with yellowish brown eggs was obtained. It was kept in the aquarium and the eggs hatched on the 24th. These zoeae turned out to be the ones referred to above. As these are very much like the zoeae of *N. pelagicus* it was deemed necessary to add a brief note pointing out the salient features.

The freshly spawned eggs are yellowish brown in colour and measure on an average 320 micra in diameter. As development progresses the 'berry' changes its colour from yellowish brown to brownish black.

Pre-zoea (Fig. 49). The eggs hatch out as the pre-zoeae. All the spines are telescopic but are shorter than those of the corresponding stage of *N. pelagicus*. The thoracic appendages have their setae retracted and the forks of the telson are not fully extended. The embryonic cuticle is cast off by the pre-zoea in a short time and it develops gradually the characters of the fully developed first zoea.

First zoea (Fig. 50). The rostral spine is 0.23 mm. and the posterior spine, which has a curved tip, is 0.275 mm. in length.

First antenna (Fig. 51) is single jointed and bears three terminal aesthetes.

Second antenna (Fig. 52). The spiniform process which is about the length of the rostral spine has fewer spines than in the corresponding zoea stage of *N. pelagicus*. The flagellum is absent at this stage.

Mandible (Fig. 53) is a short piece with irregular teeth.

First maxilla (Fig. 54). No epipodital hair. The coxopodite bears six setose spines, whereas the basipodite has five of which one is a simple spine. The endopodite is two jointed and the distal segment has six setae.

Second maxilla (Fig. 55) has five and eight spinous setae on the coxopodite and basipodite respectively while the endopodite bears only four setae. The scaphognathite has five plumose setae along its margin.

First and second maxillipeds (Figs. 56 and 57) have the same structure as those of the first zoea of *N. pelagicus*.

Abdomen has five segments and the telson. A pair of short dorsal hairs are present on all the segments. Segments two and three have a pair of short lateral spines. Postero-lateral spines are present on segments three to five.

Telson (Fig. 58) is deeply forked. In size and general shape it is different from that of the zoea of *N. pelagicus*. As can be seen from the Figures 18 and 58 the position of the lateral and dorsal spines on the forks of the telson is different in the two species. The spines between the forks are more or less similar in both.

The zoea of *Thalamita crenata* thus shows striking similarities but can be distinguished from that of *N. pelagicus* by the differences mentioned above.

SUMMARY

1. The habits and habitat of *N. pelagicus* have been briefly described. Segregation according to size has been noticed. There is a greater proportion of males in the catches which may indicate schooling according to sex. There is apparently no such segregation by sex among the smaller ones.

2. Observations made suggest that the breeding season in the species is protracted but the maximum breeding takes place during September to March.

3. The species exhibits marked sexual dimorphism. The females attain maturity when they are 106 to 108 mm. across the carapace. The males seem to mature at a smaller size.

4. The eggs and the various developmental stages up to the second post-larval instar have been described from larvae reared in the laboratory as well as from those obtained in the plankton.

5. The larvae hatch as the pre-zoea and pass through three zoeal stages before becoming the megalopa. The megalopa moults directly into the first post-larval instar. At this stage they take to a bottom life.

6. A brief description of the zoea of *Thalanita crenata*, another common Portunid occurring in this area, has been given.

REFERENCES

- Churchill, E. P. (1918): Life history of the blue crab. *Bull. U.S. Bureau of Fisheries* **36**: 95-128.
- — — (1941): The zoeal stages of the blue crab, *Callinectes sapidus*. *Anat. Rec.*, **81** (Suppl.): 37-38.
- — — (1942): The zoeal stages of the blue crab, *Callinectes sapidus* Rathbun. Publ. No. 49, Chesapeake Biol. Lab.
- Clever, F. C. (1949): Preliminary results of the coastal crab (*Cancer magister*) investigations. Dept. of Fisheries, State of Washington, *Biol. Rept.* No. 49A: 47-82.
- Delsman, H. C., & J. C. De Man, (1925): On the 'Radjungans' of the Bay of Batavia. *Treubia*, **6**: 308-323.
- George, A. I. (1943): Preliminary observations on the occurrence of a new species of Rhizocephalan on *Neptunus pelagicus* from Madras coast. *Proc. 30th Indian Sci. Congress*, Pt. 3: 58.
- Hay, W. P. (1905): The life history of the blue crab. *Rept. U.S. Bur. Fish.* 1904: 397-413.
- Hopkins, S. H. (1943): The external morphology of the first and second zoeal stages of the blue crab, *Callinectes sapidus* Rathbun. *Trans. Amer. Micros. Soc.*, **62**: 85-90.
- — — (1944): The external morphology of the third and fourth zoeal stages of the blue crab, *Callinectes sapidus* Rathbun. *Biol. Bull.*, **87**: 145-152.
- Kemp, S. (1915): Fauna of the Chilka Lake. Crustacea, Decapoda. *Mem. Indian Mus.*, **5**: 199-325.
- Lebour, M. V. (1928): The larval stages of the Plymouth Brachyura. *Proc. Zool. Soc., London*, **2**: 473-560.
- MacGinitie, G. E., & Nettie MacGinitie, (1949): Natural history of marine animals. McGraw-Hill Book Co., New York.
- Pearson, J. (1908): Cancer. *Liverpool Mar. Biol. Comm. Mem.*, **16**: 1-217.
- Prasad, R. R., & P. R. Sadasivan Tampi, (1951): An account of the fishery and fishing methods for *Neptunus pelagicus* (Linn.) near Mandapam. *J. Zool. Soc., India*, **3**: 335-339.
- Sandoz, M., & S. H. Hopkins, (1944): Zoeal larvae of the blue crab, *Callinectes sapidus* Rathbun. *Jour. Washington Acad. Sci.*, **34**: 132-133.
- Stead, D. G. (1898): Contributions to knowledge of the Australian crustacean fauna. I. Observations on the genus *Neptunus*. *Proc. Linn. Soc., New South Wales*, **23**: 746-758.
- Thomson, J. M. (1951): Catch composition of the Sand crab, fishery in Moreton Bay. *Australian Jour. Mar. and Freshwater Res.*, **2**: 237-244.
- Yonge, C. M. (1937): The nature and significance of the membranes surrounding the developing eggs of *Homarus vulgaris* and other Decapoda. *Proc. Zool. Soc., London*, **107**, Ser. A: 499-517.